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Zhou et al.

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(54) **METHODS AND APPARATUS FOR BEAM FAILURE DETECTION**

(71) Applicant: **QUALCOMM Incorporated**, San Diego, CA (US)

(72) Inventors: **Yan Zhou**, San Diego, CA (US); **Tao Luo**, San Diego, CA (US); **Prashanth Haridas Hande**, San Diego, CA (US); **Makesh Pravin John Wilson**, San Diego, CA (US)

(73) Assignee: **QUALCOMM Incorporated**, San Diego, CA (US)

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H04M 3/26	(2006.01)
H04W 72/04	(2009.01)
H04L 5/00	(2006.01)

(52) **U.S. Cl.**

CPC ***H04M 3/26*** (2013.01); ***H04L 5/001*** (2013.01); ***H04W 72/042*** (2013.01)

(58) **Field of Classification Search**

CPC H04M 3/26; H04L 5/001; H04L 5/005; H04L 5/0048; H04L 5/0051; H04L 5/0053; H04W 72/042; H04W 72/02; H04W 72/04

USPC 370/216–218

See application file for complete search history.

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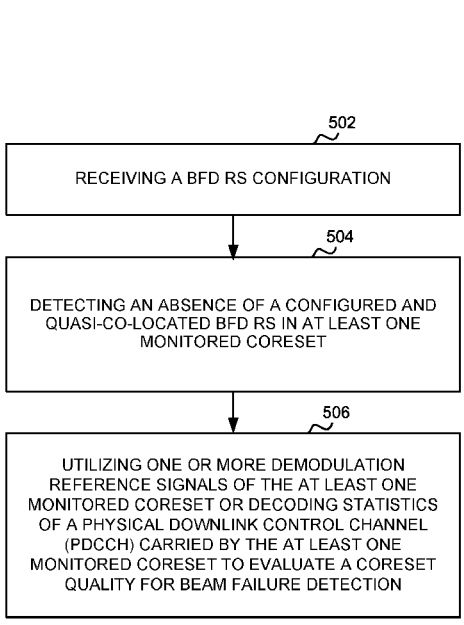
Primary Examiner — Candal Elpenord

(74) *Attorney, Agent, or Firm* — QUALCOMM Incorporated

(57) **ABSTRACT**

An aspect of the present disclosure includes methods, systems, and computer-readable media for receiving a beam failure detection reference signal configuration, detecting an absence of a configured and quasi-co-located beam failure detection reference signal in a monitored control resource set (CORESET), and utilizing reference signals indicated in the CORESET transmission configuration indicator state for beam failure detection.

21 Claims, 6 Drawing Sheets



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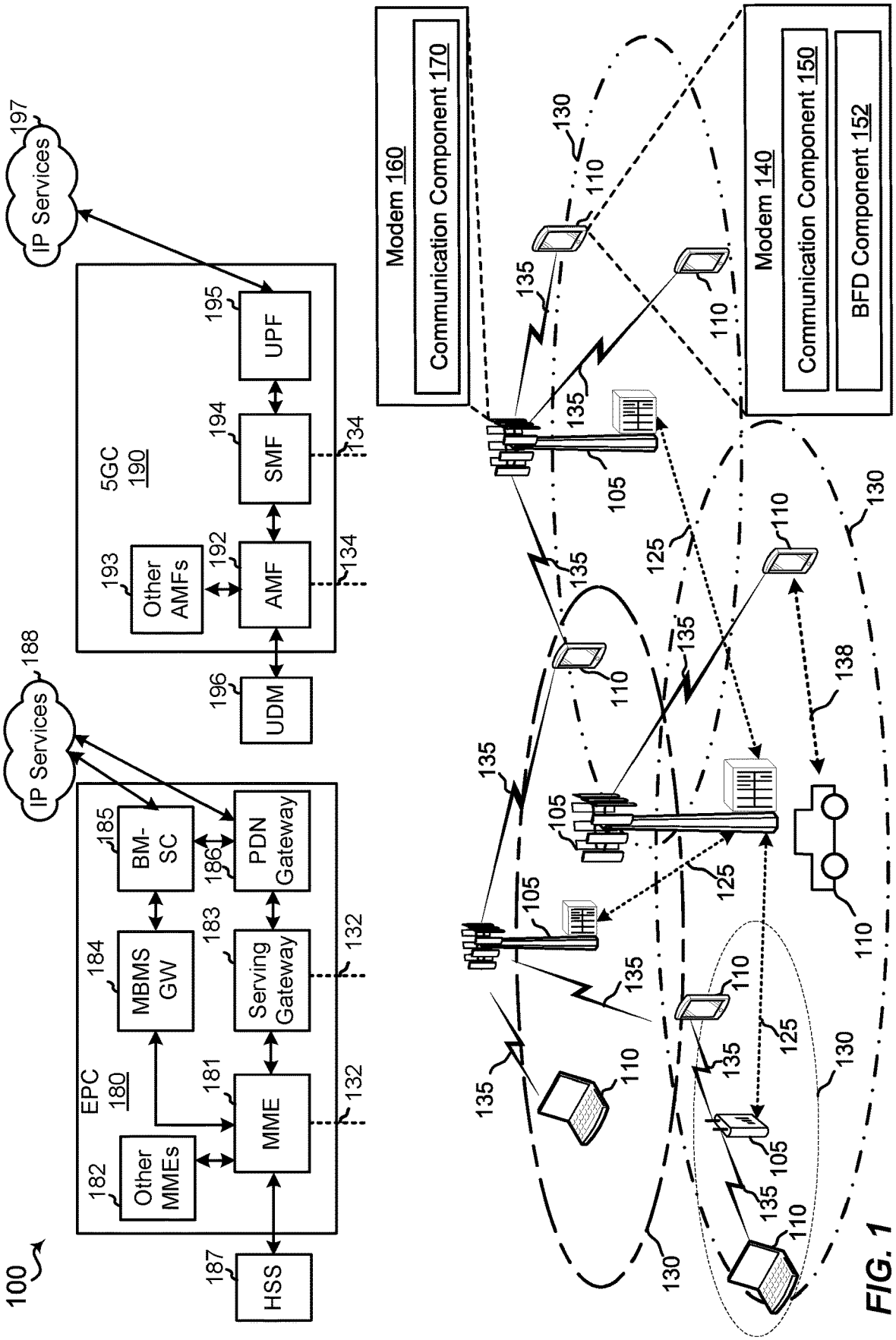
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IP Services
197
5GC
190
UPF
195
SMF
194
AMF
192
Other AMFs
193
UDM
196
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IP Services
188
EPC
180
BM-SC
185
PDN Gateway
186
MBMS GW
184
Serving Gateway
183
MME
181
Other MMEs
182
HSS
187
132
Modem 160
Communication Component 170
Modem 140
Communication Component 150
BFD Component 152
105
110
125
130
135
138

FIG. 1

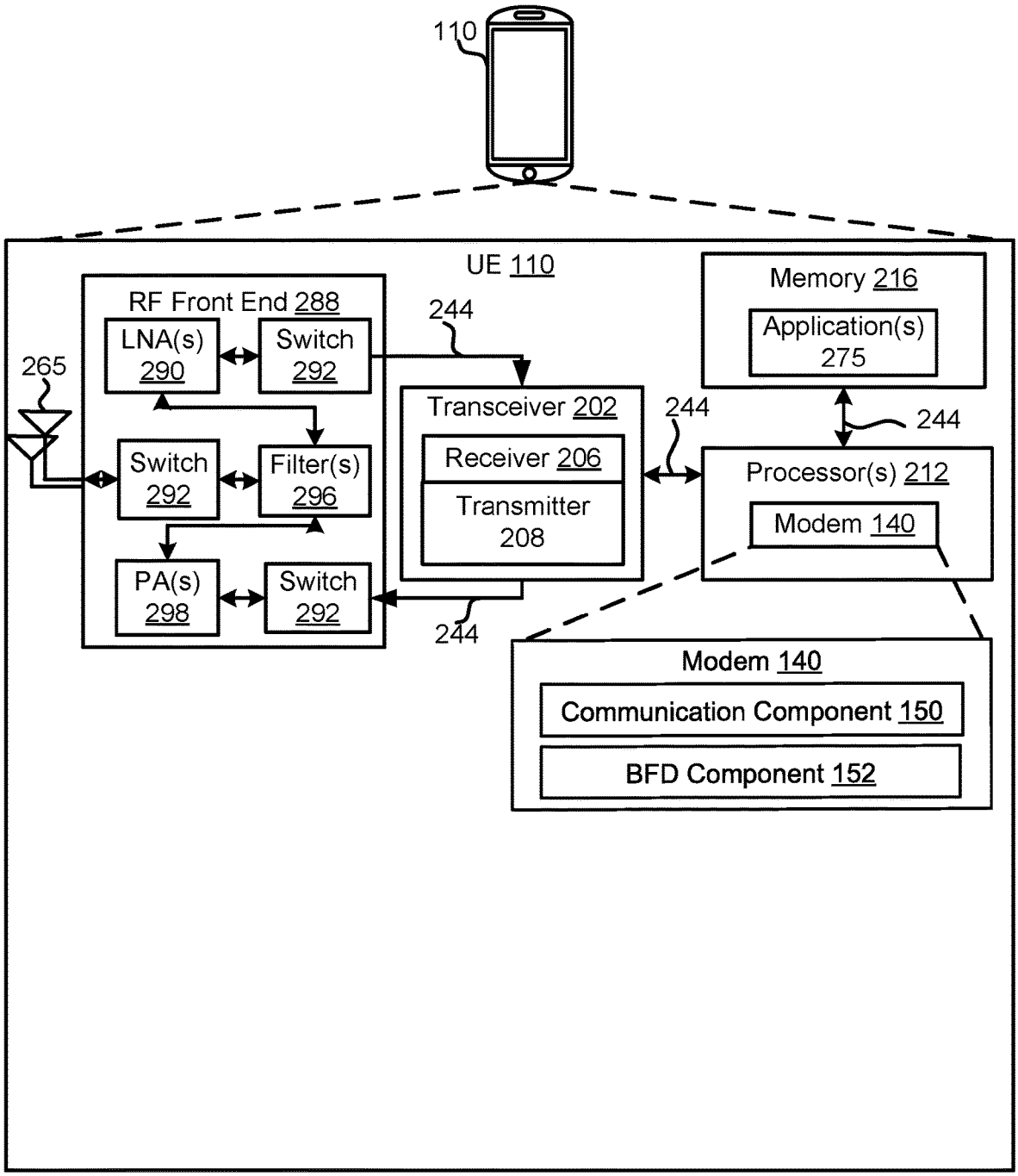
110
UE 110
RF Front End 288
LNA(s) 290
Switch 292
265
Switch 292
Filter(s) 296
PA(s) 298
Switch 292
244
Transceiver 202
Receiver 206
Transmitter 208
244
244
Memory 216
Application(s) 275
244
Processor(s) 212
Modem 140
Modem 140
Communication Component 150
BFD Component 152

FIG. 2

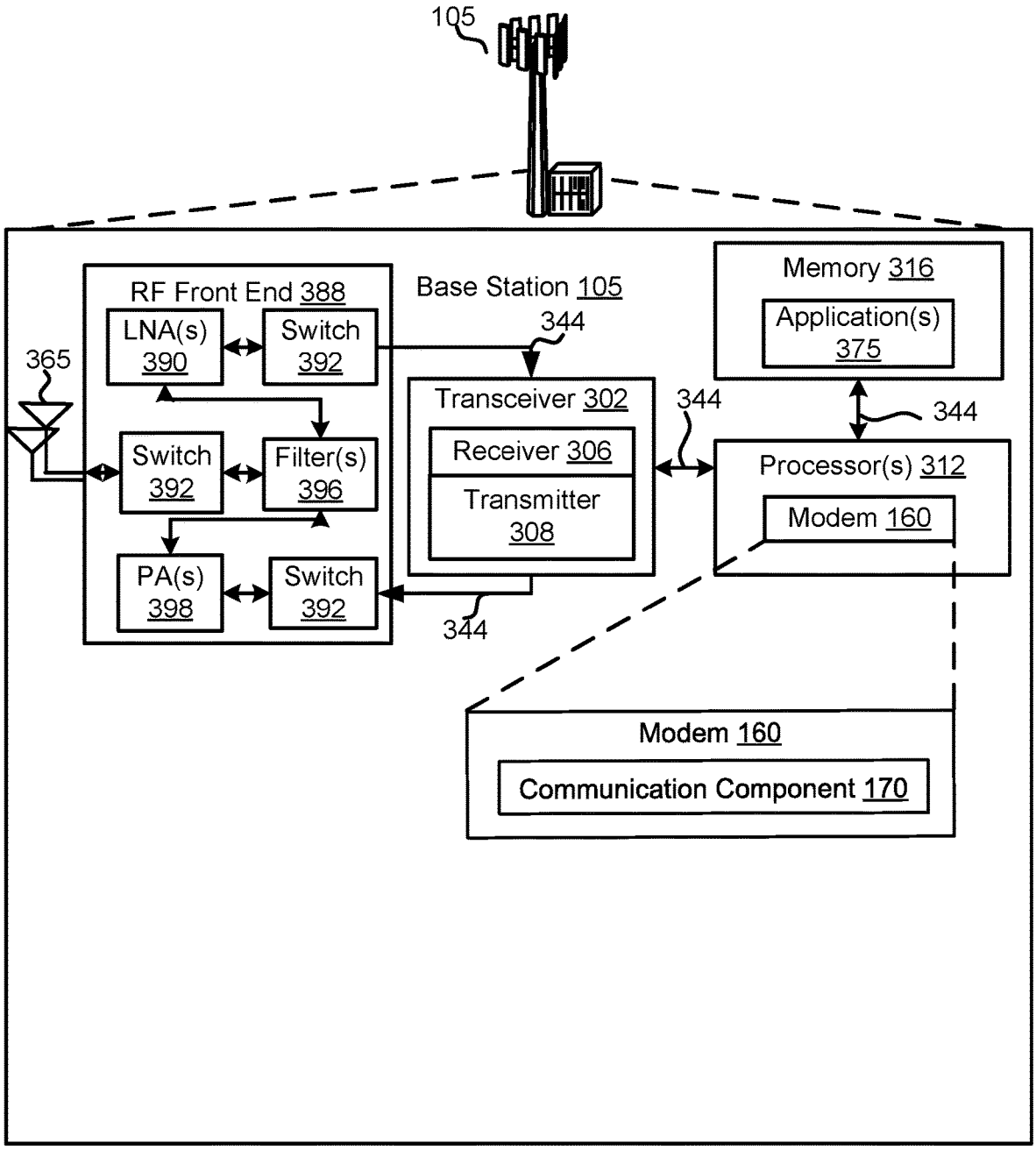
105
RF Front End 388
LNA(s) 390
Switch 392
365
Switch 392
Filter(s) 396
PA(s) 398
Switch 392
Base Station 105
344
Transceiver 302
Receiver 306
Transmitter 308
344
344
Memory 316
Application(s) 375
344
Processor(s) 312
Modem 160
Modem 160
Communication Component 170

FIG. 3

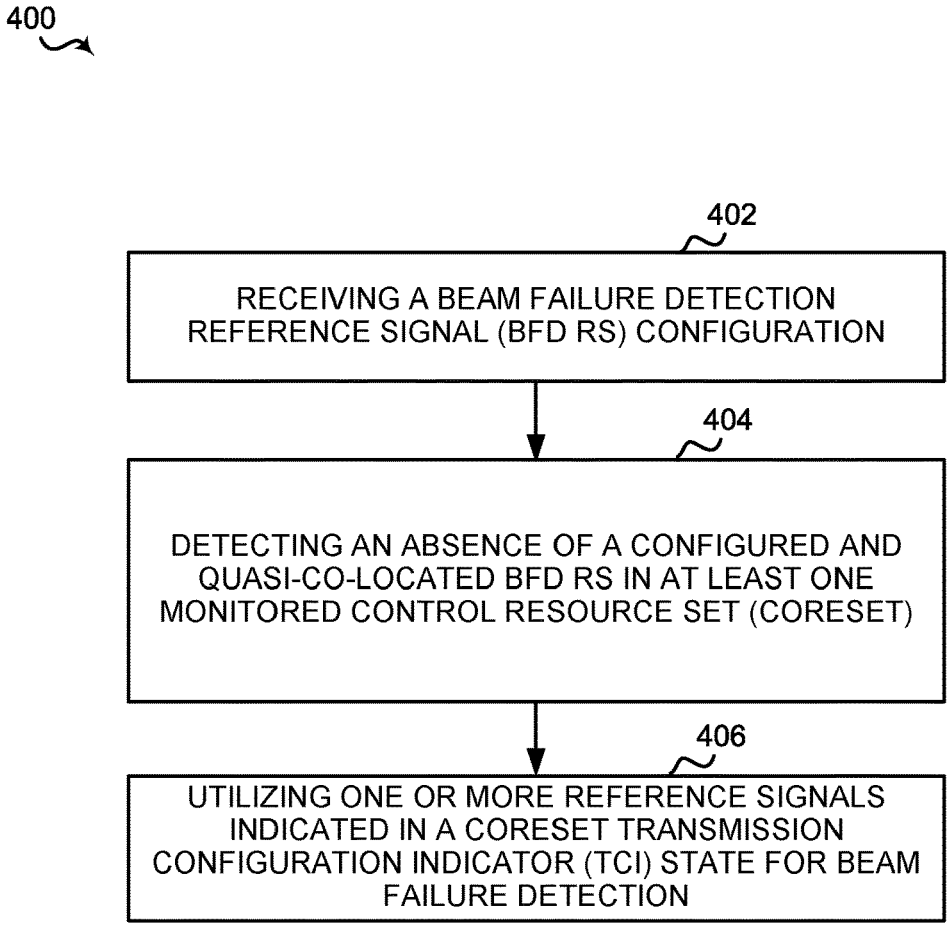
400
402
RECEIVING A BEAM FAILURE DETECTION REFERENCE SIGNAL (BFD RS) CONFIGURATION
404
DETECTING AN ABSENCE OF A CONFIGURED AND QUASI-CO-LOCATED BFD RS IN AT LEAST ONE MONITORED CONTROL RESOURCE SET (CORESET)
406
UTILIZING ONE OR MORE REFERENCE SIGNALS INDICATED IN A CORESET TRANSMISSION CONFIGURATION INDICATOR (TCI) STATE FOR BEAM FAILURE DETECTION

FIG. 4

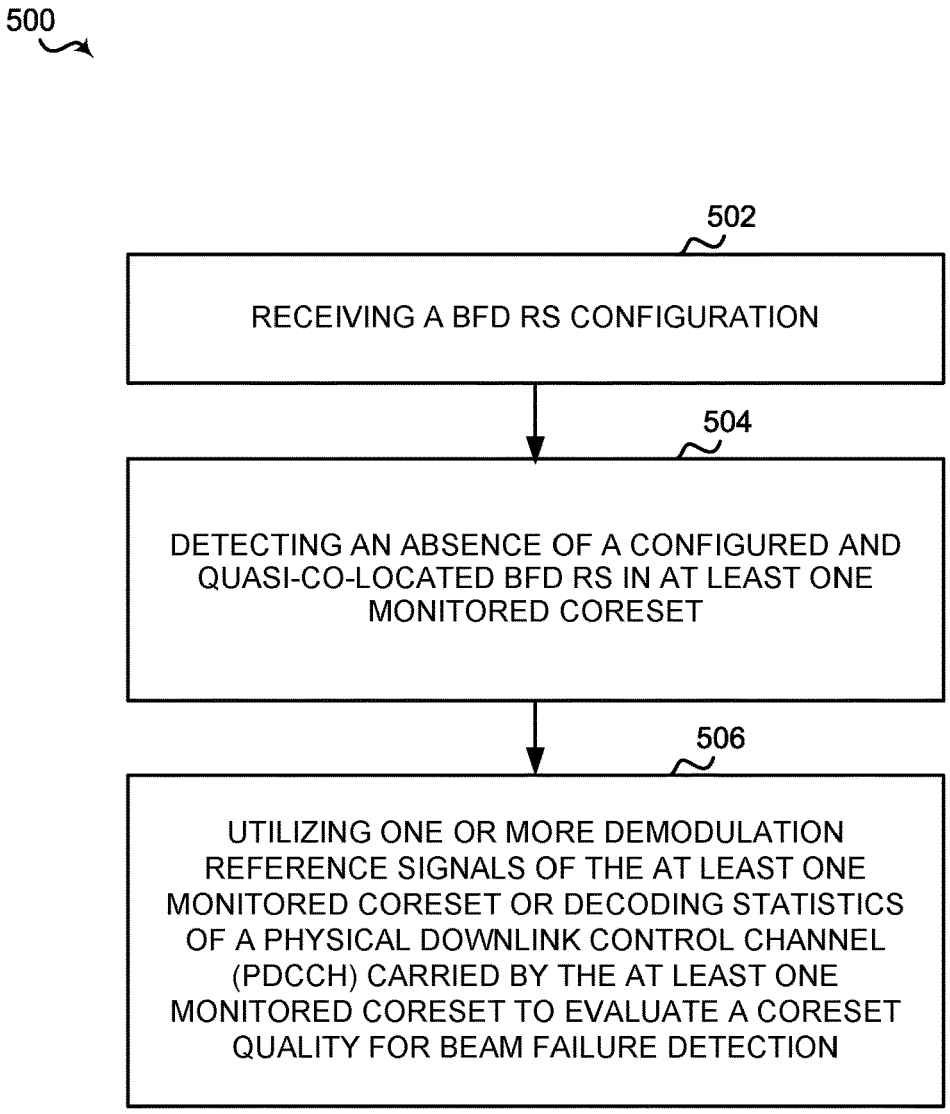
500
502
RECEIVING A BFD RS CONFIGURATION
504
DETECTING AN ABSENCE OF A CONFIGURED AND QUASI-CO-LOCATED BFD RS IN AT LEAST ONE MONITORED CORESET
506
UTILIZING ONE OR MORE DEMODULATION REFERENCE SIGNALS OF THE AT LEAST ONE MONITORED CORESET OR DECODING STATISTICS OF A PHYSICAL DOWNLINK CONTROL CHANNEL (PDCCH) CARRIED BY THE AT LEAST ONE MONITORED CORESET TO EVALUATE A CORESET QUALITY FOR BEAM FAILURE DETECTION

FIG. 5

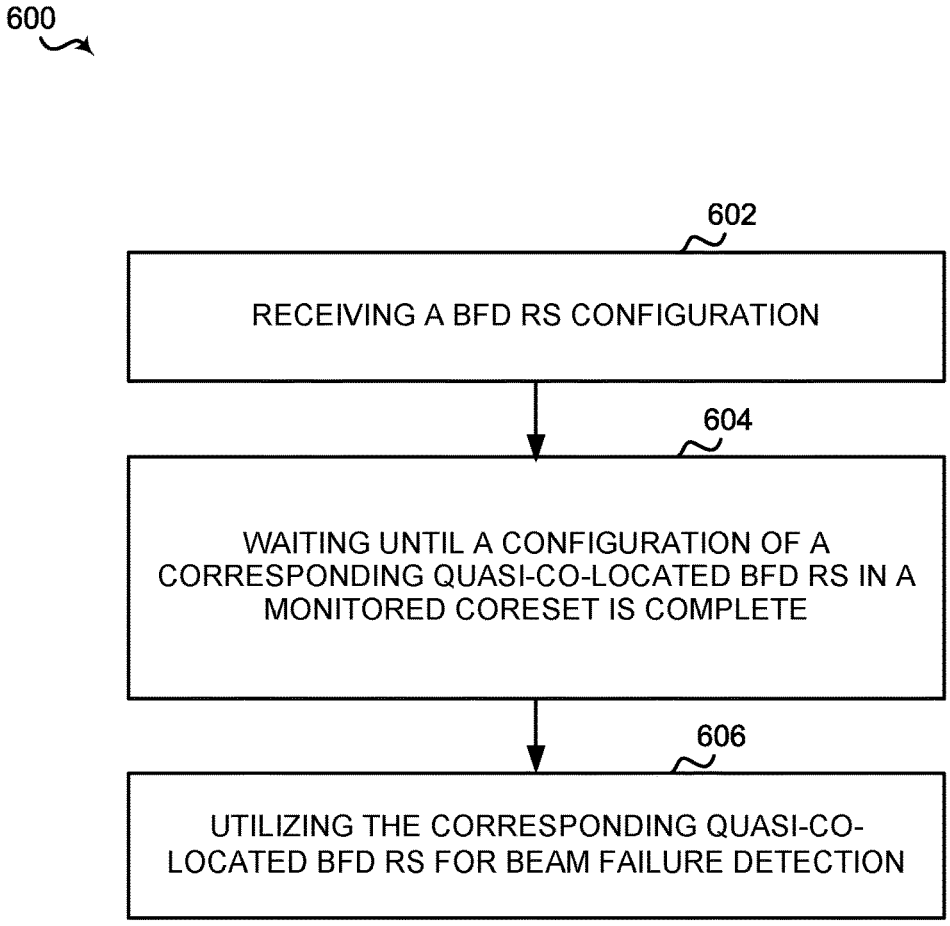
600
602
RECEIVING A BFD RS CONFIGURATION
604
WAITING UNTIL A CONFIGURATION OF A CORRESPONDING QUASI-CO-LOCATED BFD RS IN A MONITORED CORESET IS COMPLETE
606
UTILIZING THE CORRESPONDING QUASI-CO-LOCATED BFD RS FOR BEAM FAILURE DETECTION

FIG. 6

METHODS AND APPARATUS FOR BEAM FAILURE DETECTION

CROSS REFERENCE TO RELATED APPLICATIONS

The present application claims priority to U.S. Provisional Application No. 62/693,222, filed on Jul. 2, 2018, entitled "Methods and Apparatus for Beam Failure Detection," the contents of which are incorporated by reference in their entirety.

BACKGROUND

Aspects of the present disclosure relate generally to wireless communication networks, and more particularly, to apparatus and methods for beam failure detection.

Wireless communication networks are widely deployed to provide various types of communication content such as voice, video, packet data, messaging, broadcast, and so on. These systems may be multiple-access systems capable of supporting communication with multiple users by sharing the available system resources (e.g., time, frequency, and power). Examples of such multiple-access systems include code-division multiple access (CDMA) systems, time-division multiple access (TDMA) systems, frequency-division multiple access (FDMA) systems, orthogonal frequency-division multiple access (OFDMA) systems, and single-carrier frequency division multiple access (SC-FDMA) systems.

These multiple access technologies have been adopted in various telecommunication standards to provide a common protocol that enables different wireless devices to communicate on a municipal, national, regional, and even global level. For example, a fifth generation (5G) wireless communications technology (which may be referred to as new radio (NR)) is envisaged to expand and support diverse usage scenarios and applications with respect to current mobile network generations. In an aspect, 5G communications technology may include: enhanced mobile broadband addressing human-centric use cases for access to multimedia content, services and data; ultra-reliable-low latency communications (URLLC) with certain specifications for latency and reliability; and massive machine type communications, which may allow a very large number of connected devices and transmission of a relatively low volume of non-delay-sensitive information. As the demand for mobile broadband access continues to increase, however, further improvements in NR communications technology and beyond may be desired.

In a communication network, a user equipment (UE) may perform beam failure detection to assess the integrity of the transmitted signals from the base station (BS). However, certain resources may not be properly configured, due to latency for example, and difficult to be used by the UE for beam failure detection. Therefore, improvements in beam failure detection methods may be desired.

SUMMARY

The following presents a simplified summary of one or more aspects in order to provide a basic understanding of such aspects. The summary is not an extensive overview of all contemplated aspects, and is intended to neither identify key or critical elements of all aspects nor delineate the scope of any or all aspects. Its sole purpose is to present some concepts of one or more aspects in a simplified form as a prelude to the more detailed description that is presented later.

Aspects of the present disclosure include methods for receiving a beam failure detection reference signal configuration, detecting an absence of a configured and quasi-co-located beam failure detection reference signal in a monitored control resource set (CORESET), and utilizing reference signals indicated in the CORESET transmission configuration indicator state for beam failure detection.

Other aspects of the present disclosure include apparatuses having a memory, a transceiver, and one or more processors communicatively coupled with the memory and the transceiver, the one or more processors are configured to perform the steps of receiving a beam failure detection reference signal configuration, detecting an absence of a configured and quasi-co-located beam failure detection reference signal in a monitored CORESET, and utilizing reference signals indicated in the CORESET transmission configuration indicator state for beam failure detection.

Some aspects of the present disclosure include non-transitory computer readable media having instructions stored therein that, when executed by one or more processors, cause the one or more processors to perform the steps of receiving a beam failure detection reference signal configuration, detecting an absence of a configured and quasi-co-located beam failure detection reference signal in a monitored CORESET, and utilizing reference signals indicated in the CORESET transmission configuration indicator state for beam failure detection.

Aspects of the present disclosure include methods for receiving a beam failure detection reference signal configuration, detecting an absence of a configured and quasi-co-located beam failure detection reference signal in a monitored CORESET, and utilizing demodulation reference signals of the CORESET or decoding statistics of physical downlink control channel carried by the CORESET to evaluate a CORESET quality for beam failure detection.

Other aspects of the present disclosure include apparatuses having a memory, a transceiver, and one or more processors communicatively coupled with the memory and the transceiver, the one or more processors are configured to perform the steps of receiving a beam failure detection reference signal configuration, detecting an absence of a configured and quasi-co-located beam failure detection reference signal in a monitored CORESET, and utilizing demodulation reference signals of the CORESET or decoding statistics of physical downlink control channel carried by the CORESET to evaluate a CORESET quality for beam failure detection.

Some aspects of the present disclosure include non-transitory computer readable media having instructions stored therein that, when executed by one or more processors, cause the one or more processors to perform the steps of receiving a beam failure detection reference signal configuration, detecting an absence of a configured and quasi-co-located beam failure detection reference signal in a monitored CORESET, and utilizing demodulation reference signals of the CORESET or decoding statistics of physical downlink control channel carried by the CORESET to evaluate a CORESET quality for beam failure detection.

Aspects of the present disclosure include methods for receiving a beam failure detection (BFD) reference signal (RS) configuration, waiting until configuration of corresponding quasi-co-located BFD RS is complete, and utilizing the configured and quasi-co-located BFD RS for beam failure detection.

Other aspects of the present disclosure include apparatuses having a memory, a transceiver, and one or more processors communicatively coupled with the memory and the transceiver, the one or more processors are configured to perform the steps of receiving a beam failure detection reference signal configuration, waiting until configuration of a corresponding quasi-co-located BFD RS is complete, and utilizing the configured and quasi-co-located BFD RS for beam failure detection.

Some aspects of the present disclosure include non-transitory computer readable media having instructions stored therein that, when executed by one or more processors, cause the one or more processors to perform the steps of receiving a beam failure detection reference signal configuration, waiting until configuration of a corresponding quasi-co-located BFD RS is complete, and utilizing the configured and quasi-co-located BFD RS for beam failure detection.

To the accomplishment of the foregoing and related ends, the one or more aspects comprise the features hereinafter fully described and particularly pointed out in the claims. The following description and the annexed drawings set forth in detail certain illustrative features of the one or more aspects. These features are indicative, however, of but a few of the various ways in which the principles of various aspects may be employed, and the description is intended to include all such aspects and their equivalents.

BRIEF DESCRIPTION OF THE DRAWINGS

The disclosed aspects will hereinafter be described in conjunction with the appended drawings, provided to illustrate and not to limit the disclosed aspects, wherein like designations denote like elements, and in which:

FIG. **1** is a schematic diagram of an example of a wireless communication network including at least one user equipment;

FIG. **2** is a schematic diagram of an example of a user equipment;

FIG. **3** is a schematic diagram of an example of a base station;

FIG. **4** is a process flow diagram of an example of a method for performing enhanced beam failure detection using reference signals indicated in a CORESET;

FIG. **5** is a process flow diagram of an example of a method for performing enhanced beam failure detection using demodulation reference signals of a CORESET; and

FIG. **6** is a process flow diagram of an example of a method for performing enhanced beam failure detection using a configured and quasi-co-located beam failure detection reference signals.

DETAILED DESCRIPTION

The detailed description set forth below in connection with the appended drawings is intended as a description of various configurations and is not intended to represent the only configurations in which the concepts described herein may be practiced. The detailed description includes specific details for the purpose of providing a thorough understanding of various concepts. However, it will be apparent to those skilled in the art that these concepts may be practiced without these specific details. In some instances, well known structures and components are shown in block diagram form in order to avoid obscuring such concepts.

Several aspects of telecommunication systems will now be presented with reference to various apparatus and methods. These apparatus and methods will be described in the following detailed description and illustrated in the accompanying drawings by various blocks, components, circuits, processes, algorithms, etc. (collectively referred to as "elements"). These elements may be implemented using electronic hardware, computer software, or any combination thereof. Whether such elements are implemented as hardware or software depends upon the particular application and design constraints imposed on the overall system.

By way of example, an element, or any portion of an element, or any combination of elements may be implemented as a "processing system" that includes one or more processors. Examples of processors include microprocessors, microcontrollers, graphics processing units (GPUs), central processing units (CPUs), application processors, digital signal processors (DSPs), reduced instruction set computing (RISC) processors, systems on a chip (SoC), baseband processors, field programmable gate arrays (FPGAs), programmable logic devices (PLDs), state machines, gated logic, discrete hardware circuits, and other suitable hardware configured to perform the various functionality described throughout the disclosure. One or more processors in the processing system may execute software. Software shall be construed broadly to mean instructions, instruction sets, code, code segments, program code, programs, subprograms, software components, applications, software applications, software packages, routines, subroutines, objects, executables, threads of execution, procedures, functions, etc., whether referred to as software, firmware, middleware, microcode, hardware description language, or otherwise.

Accordingly, in one or more example embodiments, the functions described may be implemented in hardware, software, or any combination thereof. If implemented in software, the functions may be stored on or encoded as one or more instructions or code on a computer-readable medium, such as a computer storage media. Storage media may be any available media that may be accessed by a computer. By way of example, and not limitation, such computer-readable media may comprise a random-access memory (RAM), a read-only memory (ROM), an electrically erasable programmable ROM (EEPROM), optical disk storage, magnetic disk storage, other magnetic storage devices, combinations of the aforementioned types of computer-readable media, or any other medium that may be used to store computer executable code in the form of instructions or data structures that may be accessed by a computer.

It should be noted that the techniques described herein may be used for various wireless communication networks such as CDMA, TDMA, FDMA, OFDMA, SC-FDMA, and other systems. The terms "system" and "network" are often used interchangeably. A CDMA system may implement a radio technology such as CDMA2000, Universal Terrestrial Radio Access (UTRA), etc. CDMA2000 covers IS-2000, IS-95, and IS-856 standards. IS-2000 Releases 0 and A are commonly referred to as CDMA2000 1×, 1×, etc. IS-856 (TIA-856) is commonly referred to as CDMA2000 1×EV-DO, High Rate Packet Data (HRPD), etc. UTRA includes Wideband CDMA (WCDMA) and other variants of CDMA. A TDMA system may implement a radio technology such as Global System for Mobile Communications (GSM). An OFDMA system may implement a radio technology such as Ultra Mobile Broadband (UMB), Evolved UTRA (E-UTRA), IEEE 902.11 (Wi-Fi), IEEE 902.16 (WiMAX), IEEE 902.20, Flash-OFDM™, etc. UTRA and E-UTRA are part of Universal Mobile Telecommunication System (UMTS). 3GPP Long Term Evolution (LTE) and LTE-

Advanced (LTE-A) are new releases of UMTS that use E-UTRA. UTRA, E-UTRA, UMTS, LTE, LTE-A, and GSM are described in documents from an organization named "3rd Generation Partnership Project" (3GPP). CDMA2000 and UMB are described in documents from an organization named "3rd Generation Partnership Project 2" (3GPP2). The techniques described herein may be used for the systems and radio technologies mentioned above as well as other systems and radio technologies, including cellular (e.g., LTE) communications over a shared radio frequency spectrum band. The description below, however, describes an LTE/LTE-A and/or 5G New Radio (NR) system for purposes of example, and LTE or 5G NR terminology is used in much of the description below, although the techniques are applicable beyond LTE/LTE-A and 5G NR applications, e.g., to other next generation communication systems).

In some aspects, a UE may be explicitly configured with a set of beam failure detection (BFD) reference signals (RS). For example, the UE may be provided, by a serving cell, with a set q0 of periodic channel state information (CSI) RS resource configuration indexes by higher layer parameter failureDetectionResources. If configured, the UE may use configured BFD RSs quasi-co-located (QCLed) with monitored control resource sets (CORESETs) for beam failure detection. For the set q0, the UE may assess the radio link quality according to periodic CSI-RS resource configurations or synchronization signal/physical broadcast channel (SS/PBCH) blocks that are quasi co-located with the demodulation reference signal (DM-RS) of physical downlink control channel (PDCCH) receptions monitored by the UE.

In certain aspects, if no explicit BFD RS configuration exists, the UE may implicitly determine the set of BFD RS. For example, if the UE is not provided with higher layer parameter failureDetectionResources, the UE may determine the set to include the SS/PBCH block indexes and periodic CSI-RS resource configuration indexes with the same values as the RS indexes in the RS sets indicated by the transmission configuration indicator (TCI) states for respective control resource sets that the UE uses for monitoring PDCCH.

In some aspects, insufficient number of the configured BFD RSs may be QCLed with a monitored CORESET. In one example, the CORESET may be newly reconfigured, e.g. by media access control (MAC) control element (CE), but the configuration of the corresponding QCLed BFD RS may not have been initiated or completed due to radio resource control (RRC) configuration latency. In another example, the number of monitored CORESET (e.g., 3 per bandwidth part (BWP)) may exceed the maximal configured BFD RS number (e.g., 2 per BWP).

In some aspects, when some monitored CORESET(s) includes configured QCLed BFD RSs while other monitored CORESET(s) do not, the UE may incorrectly detect a beam failure event if the configured QCLed BFD RSs have poor quality, even if other monitored CORESETs still have good quality (e.g., hypothetic block error rate (BLER) falls below a predetermined threshold).

In other aspects, when none of configured QCLed BFD RSs is QCLed with any monitored CORESET, the UE may not be able to properly perform beam failure detection, and a beam failure event may not be announced even if all monitored CORESETS have poor quality.

In some aspects, if there is an explicit BFD RS configuration, but a monitored CORESET does not include a configured and QCLed BFD RS, the UE may use the RS(s) indicated in CORESET TCI state for BFD (e.g., at least the RS providing TypeD QCL info). Here, the UE may use the RS(s) when it is in the SS block and/or periodic CSI-RS. Alternatively, the UE may use the RS(s) when none of the monitored CORESETs has configured and QCLed BFD RS.

In other aspects, if there is an explicit BFD RS configuration, but a monitored CORESET does not include configured and QCLed BFD RS, the UE may use the DM-RS of the CORESET or decode the statistics of PDCCH carried by the CORESET to evaluate the CORESET quality for BFD.

In certain aspects, a MAC CE based BFD RS configuration/reconfiguration may be introduced to reduce the latency of RRC configuration/reconfiguration. The CORESET and corresponding QCLed BFD-RS may be configured/reconfigured simultaneously by a single MAC-CE or multiple MAC-CEs in a same frame, or in different frames but close in time (e.g., in adjacent slots of the resource elements).

In other aspects, for example, if there is explicit BFD RS configuration, a CORESET may not be used until the configuration of the corresponding QCLed BFD RS is completed.

Referring to FIG. **1**, in accordance with various aspects of the present disclosure, a wireless communication network **100** includes at least one UE **110** including a modem **140**. The modem **140** may include a communication component **150** configured to communicate with the other UEs **110** and/or base stations **105**, such as sending/receiving messages to the other UEs **110** and/or base stations **105**. The modem **140** may include a BFD component **152** configured to detect a beam failure event using resources available to the UE **110**.

The wireless network may include at least one base station **105** including a modem **160**. The modem **160** may include a communication component **170** configured to communicate with one or more UEs **110** and/or other base stations **105**, such as sending/receiving messages to the UEs **110** and/or other base stations **105**.

The modem **160** of a base station **105** may be configured to communicate with other base stations **105** and UEs **110** via a cellular network, a Wi-Fi network, or other wireless and wired networks. The modem **140** of a UE **110** may be configured to communicate with the base stations **105** via a cellular network, a Wi-Fi network, or other wireless and wired networks. The modems **140**, **160** may receive and transmit data packets.

The wireless communication network **100** may include one or more base stations **105**, one or more UEs **110**, and a core network, such as an Evolved Packet Core (EPC) **180** and/or a 5G core (5GC) **190**. The EPC **180** and/or the 5GC **190** may provide user authentication, access authorization, tracking, internet protocol (IP) connectivity, and other access, routing, or mobility functions. The base stations **105** configured for 4G LTE (collectively referred to as Evolved Universal Mobile Telecommunications System (UMTS) Terrestrial Radio Access Network (E-UTRAN)) may interface with the EPC **180** through backhaul links **132** (e.g., S1, etc.). The base stations **105** configured for 5G NR (collectively referred to as Next Generation RAN (NG-RAN)) may interface with the 5GC **190** through backhaul links **134**. In addition to other functions, the base stations **105** may perform one or more of the following functions: transfer of user data, radio channel ciphering and deciphering, integrity protection, header compression, mobility control functions (e.g., handover, dual connectivity), inter-cell interference coordination, connection setup and release, load balancing, distribution for non-access stratum (NAS) messages, NAS node selection, synchronization, radio access network (RAN) sharing, multimedia broadcast multicast service

(MBMS), subscriber and equipment trace, RAN information management (RIM), paging, positioning, and delivery of warning messages. The base stations **105** may communicate with each other directly or indirectly (e.g., through the EPC **180** or the 5GC **190**), with one another over backhaul links **125**, **132**, or **134** (e.g., Xn, X1, or X2 interfaces). The backhaul links **125**, **132**, **134** may be wired or wireless communication links.

The base stations **105** may wirelessly communicate with the UEs **110** via one or more antennas. Each of the base stations **105** may provide communication coverage for a respective geographic coverage area **130**. In some examples, the base stations **105** may be referred to as a base station, a radio base station, an access point (AP), an access node, a radio transceiver, a NodeB, eNodeB (eNB), gNodeB (gNB), Home NodeB, a Home eNodeB, a relay, a transceiver function, a basic service set (BSS), an extended service set (ESS), a transmit reception point (TRP), or some other suitable terminology. The geographic coverage area **130** for a base station **105** may be divided into sectors or cells making up only a portion of the coverage area (not shown). The wireless communication network **100** may include base stations **105** of different types (e.g., macro cell base stations or small cell base stations, described below). Additionally, the plurality of base stations **105** may operate according to different ones of a plurality of communication technologies (e.g., 5G (New Radio or "NR"), fourth generation (4G)/LTE, 3G, Wi-Fi, Bluetooth, etc.), and thus there may be overlapping geographic coverage areas **130** for different communication technologies.

In some examples, the wireless communication network **100** may be or include one or any combination of communication technologies, including a NR or 5G technology, a LTE or LTE-Advanced (LTE-A) or MuLTEfire technology, a Wi-Fi technology, a Bluetooth technology, or any other long or short range wireless communication technology. In LTE/LTE-A/MuLTEfire networks, the term evolved node B (eNB) may be generally used to describe the base stations **105**, while the term UE may be generally used to describe the UEs **110**. The wireless communication network **100** may be a heterogeneous technology network in which different types of eNBs provide coverage for various geographical regions. For example, each eNB or base station **105** may provide communication coverage for a macro cell, a small cell, or other types of cell.

A macro cell may generally cover a relatively large geographic area (e.g., several kilometers in radius) and may allow unrestricted access by UEs **110** with service subscriptions with the network provider.

A small cell may include a relative lower transmit-powered base station, as compared with a macro cell, that may operate in the same or different frequency bands (e.g., licensed, unlicensed, etc.) as macro cells. Small cells may include pico cells, femto cells, and micro cells according to various examples. A pico cell, for example, may cover a small geographic area and may allow unrestricted access by UEs **110** with service subscriptions with the network provider. A femto cell may also cover a small geographic area (e.g., a home) and may provide restricted access and/or unrestricted access by UEs **110** having an association with the femto cell (e.g., in the restricted access case, UEs **110** in a closed subscriber group (CSG) of the base station **105**, which may include UEs **110** for users in the home, and the like). An eNB for a macro cell may be referred to as a macro eNB. An eNB for a small cell may be referred to as a small cell eNB, a pico eNB, a femto eNB, or a home eNB. An eNB may support one or multiple (e.g., two, three, four, and the like) cells (e.g., component carriers).

The communication networks that may accommodate some of the various disclosed examples may be packet-based networks that operate according to a layered protocol stack and data in the user plane may be based on the IP. A user plane protocol stack (e.g., packet data convergence protocol (PDCP), radio link control (RLC), MAC, etc.), may perform packet segmentation and reassembly to communicate over logical channels. For example, a MAC layer may perform priority handling and multiplexing of logical channels into transport channels. The MAC layer may also use hybrid automatic repeat/request (HARQ) to provide retransmission at the MAC layer to improve link efficiency. In the control plane, the RRC protocol layer may provide establishment, configuration, and maintenance of an RRC connection between a UE **110** and the base stations **105**. The RRC protocol layer may also be used for the EPC **180** or the 5GC **190** support of radio bearers for the user plane data. At the physical (PHY) layer, the transport channels may be mapped to physical channels.

The UEs **110** may be dispersed throughout the wireless communication network **100**, and each UE **110** may be stationary or mobile. A UE **110** may also include or be referred to by those skilled in the art as a mobile station, a subscriber station, a mobile unit, a subscriber unit, a wireless unit, a remote unit, a mobile device, a wireless device, a wireless communications device, a remote device, a mobile subscriber station, an access terminal, a mobile terminal, a wireless terminal, a remote terminal, a handset, a user agent, a mobile client, a client, or some other suitable terminology. A UE **110** may be a cellular phone, a smart phone, a personal digital assistant (PDA), a wireless modem, a wireless communication device, a handheld device, a tablet computer, a laptop computer, a cordless phone, a smart watch, a wireless local loop (WLL) station, an entertainment device, a vehicular component, a customer premises equipment (CPE), or any device capable of communicating in wireless communication network **100**. Some non-limiting examples of UEs **110** may include a session initiation protocol (SIP) phone, a satellite radio, a global positioning system, a multimedia device, a video device, a digital audio player (e.g., MP3 player), a camera, a game console, a smart device, a wearable device, a vehicle, an electric meter, a gas pump, a large or small kitchen appliance, a healthcare device, an implant, a sensor/actuator, a display, or any other similar functioning device. Additionally, a UE **110** may be Internet of Things (IoT) and/or machine-to-machine (M2M) type of device, e.g., a low power, low data rate (relative to a wireless phone, for example) type of device, that may in some aspects communicate infrequently with wireless communication network **100** or other UEs. Some examples of IoT devices may include parking meter, gas pump, toaster, vehicles, and heart monitor. A UE **110** may be able to communicate with various types of base stations **105** and network equipment including macro eNBs, small cell eNBs, macro gNBs, small cell gNBs, relay base stations, and the like.

UE **110** may be configured to establish one or more wireless communication links **135** with one or more base stations **105**. The wireless communication links **135** shown in wireless communication network **100** may carry uplink (UL) transmissions from a UE **110** to a base station **105**, or downlink (DL) transmissions, from a base station **105** to a UE **110**. The downlink transmissions may also be called forward link transmissions while the uplink transmissions may also be called reverse link transmissions. Each wireless communication link **135** may include one or more carriers,

where each carrier may be a signal made up of multiple sub-carriers (e.g., waveform signals of different frequencies) modulated according to the various radio technologies described above. Each modulated signal may be sent on a different sub-carrier and may carry control information (e.g., reference signals, control channels, etc.), overhead information, user data, etc. In an aspect, the wireless communication links **135** may transmit bidirectional communications using FDD (e.g., using paired spectrum resources) or TDD operation (e.g., using unpaired spectrum resources). Frame structures may be defined for FDD (e.g., frame structure type 1) and TDD (e.g., frame structure type 2). Moreover, in some aspects, the wireless communication links **135** may represent one or more broadcast channels.

In some aspects of the wireless communication network **100**, base stations **105** or UEs **110** may include multiple antennas for employing antenna diversity schemes to improve communication quality and reliability between base stations **105** and UEs **110**. Additionally or alternatively, base stations **105** or UEs **110** may employ MIMO techniques that may take advantage of multi-path environments to transmit multiple spatial layers carrying the same or different coded data.

Wireless communication network **100** may support operation on multiple cells or carriers, such as carrier aggregation (CA) or multi-carrier operation. The terms "carrier," "component carrier," "cell," and "channel" may be used interchangeably herein. A UE **110** may be configured with multiple downlink component carriers (CCs) and one or more uplink CCs for carrier aggregation. Carrier aggregation may be used with both FDD and TDD component carriers. The communication links **135** may use multiple-input and multiple-output (MIMO) antenna technology, including spatial multiplexing, beamforming, and/or transmit diversity. The base stations **105** and/or UEs **110** may use spectrum up to Y MHz (e.g., 5, 10, 15, 20, 30, 50, 100, 200, 400, etc., MHz) bandwidth per carrier allocated in a carrier aggregation of up to a total of Yx MHz (x=number of component carriers) used for transmission in each direction. The carriers may or may not be adjacent to each other. Allocation of carriers may be asymmetric with respect to DL and UL (e.g., more or less carriers may be allocated for DL than for UL). The component carriers may include a primary component carrier and one or more secondary component carriers. A primary component carrier may be referred to as a primary cell (PCell) and a secondary component carrier may be referred to as a secondary cell (SCell).

Certain UEs **110** may communicate with each other using device-to-device (D2D) communication link **138**. The D2D communication link **138** may use the DL/UL WWAN spectrum. The D2D communication link **138** may use one or more sidelink channels, such as a physical sidelink broadcast channel (PSBCH), a physical sidelink discovery channel (PSDCH), a physical sidelink shared channel (PSSCH), and a physical sidelink control channel (PSCCH). D2D communication may be through a variety of wireless D2D communications systems, such as for example, FlashLinQ, WiMedia, Bluetooth, ZigBee, Wi-Fi based on the IEEE 802.11 standard, LTE, or NR.

The wireless communications network **100** may further include base stations **105** operating according to Wi-Fi technology, e.g., Wi-Fi access points, in communication with UEs **110** operating according to Wi-Fi technology, e.g., Wi-Fi stations (STAs) via communication links in an unlicensed frequency spectrum (e.g., 5 GHz). When communicating in an unlicensed frequency spectrum, the STAs and AP may perform a clear channel assessment (CCA) or listen before talk (LBT) procedure prior to communicating in order to determine whether the channel is available.

The small cell may operate in a licensed and/or an unlicensed frequency spectrum. When operating in an unlicensed frequency spectrum, the small cell may employ NR and use the same 5 GHz unlicensed frequency spectrum as used by the Wi-Fi AP. The small cell, employing NR in an unlicensed frequency spectrum, may boost coverage to and/or increase capacity of the access network.

A base station **105**, whether a small cell or a large cell (e.g., macro base station), may include an eNB, gNodeB (gNB), or other type of base station. Some base stations **105**, such as a gNB may operate in a traditional sub 6 GHz spectrum, in millimeter wave (mmW) frequencies and/or near mmW frequencies in communication with the UE **110**. When the gNB, such as a base station **105** operates in mmW or near mmW frequencies, the base station **105** may be referred to as an mmW base station. Extremely high frequency (EHF) is part of the radio frequency (RF) in the electromagnetic spectrum. EHF has a range of 30 GHz to 300 GHz and a wavelength between 1 millimeter and 10 millimeters. Radio waves in the band may be referred to as a millimeter wave. Near mmW may extend down to a frequency of 3 GHz with a wavelength of 100 millimeters. The super high frequency (SHF) band extends between 3 GHz and 30 GHz, and may also be referred to as centimeter wave. Communications using the mmW and/or near mmW radio frequency band has extremely high path loss and a short range. The mmW base station **105** may utilize beamforming with the UEs **110** in their transmissions to compensate for the extremely high path loss and short range.

In a non-limiting example, the EPC **180** may include a Mobility Management Entity (MME) **181**, other MMEs **182**, a Serving Gateway **183**, a Multimedia Broadcast Multicast Service (MBMS) Gateway **184**, a Broadcast Multicast Service Center (BM-SC) **185**, and a Packet Data Network (PDN) Gateway **186**. The MME **181** may be in communication with a Home Subscriber Server (HSS) **187**. The MME **181** is the control node that processes the signaling between the UEs **110** and the EPC **180**. Generally, the MME **181** provides bearer and connection management. All user Internet protocol (IP) packets are transferred through the Serving Gateway **183**, which itself is connected to the PDN Gateway **186**. The PDN Gateway **186** provides UE IP address allocation as well as other functions. The PDN Gateway **186** and the BM-SC **185** are connected to the IP Services **188**. The IP Services **188** may include the Internet, an intranet, an IP Multimedia Subsystem (IMS), a PS Streaming Service, and/or other IP services. The BM-SC **185** may provide functions for MBMS user service provisioning and delivery. The BM-SC **185** may serve as an entry point for content provider MBMS transmission, may be used to authorize and initiate MBMS Bearer Services within a public land mobile network (PLMN), and may be used to schedule MBMS transmissions. The MBMS Gateway **184** may be used to distribute MBMS traffic to the base stations **105** belonging to a Multicast Broadcast Single Frequency Network (MBSFN) area broadcasting a particular service, and may be responsible for session management (start/stop) and for collecting eMBMS related charging information.

The 5GC **190** may include a Access and Mobility Management Function (AMF) **192**, other AMFs **193**, a Session Management Function (SMF) **194**, and a User Plane Function (UPF) **195**. The AMF **192** may be in communication with a Unified Data Management (UDM) **196**. The AMF **192** is the control node that processes the signaling between the UEs **110** and the 5GC **190**. Generally, the AMF **192**

provides QoS flow and session management. All user Internet protocol (IP) packets are transferred through the UPF **195**. The UPF **195** provides UE IP address allocation as well as other functions. The UPF **195** is connected to the IP Services **197**. The IP Services **197** may include the Internet, an intranet, an IP Multimedia Subsystem (IMS), a PS Streaming Service, and/or other IP services.

Referring to FIG. **2**, one example of an implementation of the UE **110** may include a variety of components, some of which have already been described above, but including components such as one or more processors **212** and memory **216** and transceiver **202** in communication via one or more buses **244**, which may operate in conjunction with the modem **140**, the communication component **150**, and/or the BFD component **152** to enable one or more of the functions described herein related to communicating with the base station **105**. Further, the one or more processors **212**, modem **140**, memory **216**, transceiver **202**, RF front end **288** and one or more antennas **265**, may be configured to support voice and/or data calls (simultaneously or non-simultaneously) in one or more radio access technologies. The one or more antennas **265** may include stand-alone antennas and/or antenna arrays.

In an aspect, the one or more processors **212** may include the modem **140** that uses one or more modem processors. The various functions related to the communication component **150** and the BFD component **152** may be included in the modem **140** and/or processors **212** and, in an aspect, may be executed by a single processor, while in other aspects, different ones of the functions may be executed by a combination of two or more different processors. For example, in an aspect, the one or more processors **212** may include any one or any combination of a modem processor, or a baseband processor, or a digital signal processor, or a transmit processor, or a receiver processor, or a transceiver processor associated with transceiver **202**. Additionally, the modem **140** may configure the UE **110** along with the BFD component **152** and the processors **212**. In other aspects, some of the features of the one or more processors **212** and/or the modem **140** associated with the communication component **150** may be performed by transceiver **202**.

Also, memory **216** may be configured to store data used herein and/or local versions of applications **275** or the communication component **150** and/or one or more subcomponents of the communication component **150** being executed by at least one processor **212**. Memory **216** may include any type of computer-readable medium usable by a computer or at least one processor **212**, such as random access memory (RAM), read only memory (ROM), tapes, magnetic discs, optical discs, volatile memory, non-volatile memory, and any combination thereof. In an aspect, for example, memory **216** may be a non-transitory computer-readable storage medium that stores one or more computer-executable codes defining the communication component **150** and/or one or more of its subcomponents, and/or data associated therewith, when UE **110** is operating at least one processor **212** to execute the communication component **150** and the BFD component **152** and/or one or more of their subcomponents.

Transceiver **202** may include at least one receiver **206** and at least one transmitter **208**. Receiver **206** may include hardware, firmware, and/or software code executable by a processor for receiving data, the code comprising instructions and being stored in a memory (e.g., computer-readable medium). Receiver **206** may be, for example, a radio frequency (RF) receiver. In an aspect, receiver **206** may receive signals transmitted by at least one base station **105**. Transmitter **208** may include hardware, firmware, and/or software code executable by a processor for transmitting data, the code comprising instructions and being stored in a memory (e.g., computer-readable medium). A suitable example of transmitter **208** may including, but is not limited to, an RF transmitter.

Moreover, in an aspect, UE **110** may include RF front end **288**, which may operate in communication with one or more antennas **265** and transceiver **202** for receiving and transmitting radio transmissions, for example, wireless communications transmitted by at least one base station **105** or wireless transmissions transmitted by UE **110**. RF front end **288** may be coupled with one or more antennas **265** and may include one or more low-noise amplifiers (LNAs) **290**, one or more switches **292**, one or more power amplifiers (PAs) **298**, and one or more filters **296** for transmitting and receiving RF signals.

In an aspect, LNA **290** may amplify a received signal at a desired output level. In an aspect, each LNA **290** may have a specified minimum and maximum gain values. In an aspect, RF front end **288** may use one or more switches **292** to select a particular LNA **290** and the specified gain value based on a desired gain value for a particular application.

Further, for example, one or more PA(s) **298** may be used by RF front end **288** to amplify a signal for an RF output at a desired output power level. In an aspect, each PA **298** may have specified minimum and maximum gain values. In an aspect, RF front end **288** may use one or more switches **292** to select a particular PA **298** and the specified gain value based on a desired gain value for a particular application.

Also, for example, one or more filters **296** may be used by RF front end **288** to filter a received signal to obtain an input RF signal. Similarly, in an aspect, for example, a respective filter **296** may be used to filter an output from a respective PA **298** to produce an output signal for transmission. In an aspect, each filter **296** may be coupled with a specific LNA **290** and/or PA **298**. In an aspect, RF front end **288** may use one or more switches **292** to select a transmit or receive path using a specified filter **296**, LNA **290**, and/or PA **298**, based on a configuration as specified by transceiver **202** and/or processor **212**.

As such, transceiver **202** may be configured to transmit and receive wireless signals through one or more antennas **265** via RF front end **288**. In an aspect, transceiver may be tuned to operate at specified frequencies such that UE **110** may communicate with, for example, one or more base stations **105** or one or more cells associated with one or more base stations **105**. In an aspect, for example, the modem **140** may configure transceiver **202** to operate at a specified frequency and power level based on the UE configuration of the UE **110** and the communication protocol used by the modem **140**.

In an aspect, the modem **140** may be a multiband-multimode modem, which may process digital data and communicate with transceiver **202** such that the digital data is sent and received using transceiver **202**. In an aspect, the modem **140** may be multiband and be configured to support multiple frequency bands for a specific communications protocol. In an aspect, the modem **140** may be multimode and be configured to support multiple operating networks and communications protocols. In an aspect, the modem **140** may control one or more components of UE **110** (e.g., RF front end **288**, transceiver **202**) to enable transmission and/or reception of signals from the network based on a specified modem configuration. In an aspect, the modem configuration may be based on the mode of the modem and the frequency band in use. In another aspect, the modem con-

figuration may be based on UE configuration information associated with UE **110** as provided by the network.

Referring to FIG. **3**, one example of an implementation of may include a variety of components, some of which have already been described above, but including components such as one or more processors **312** and memory **316** and transceiver **302** in communication via one or more buses **344**, which may operate in conjunction with the modem **160** and the communication component **170** to enable one or more of the functions described herein related to communicating with the UE **110**. Further, the one or more processors **312**, modem **160**, memory **316**, transceiver **302**, RF front end **388** and one or more antennas **365**, may be configured to support voice and/or data calls (simultaneously or non-simultaneously) in one or more radio access technologies. The one or more antennas **365** may include stand-alone antennas and/or antenna arrays.

In an aspect, the one or more processors **312** may include the modem **160** that uses one or more modem processors. The various functions related to the communication component **170** may be included in the modem **160** and/or processors **312** and, in an aspect, may be executed by a single processor, while in other aspects, different ones of the functions may be executed by a combination of two or more different processors. For example, in an aspect, the one or more processors **312** may include any one or any combination of a modem processor, or a baseband processor, or a digital signal processor, or a transmit processor, or a receiver processor, or a transceiver processor associated with transceiver **302**. Additionally, the modem **160** may configure the base station **105** and processors **312**. In other aspects, some of the features of the one or more processors **312** and/or the modem **160** associated with the communication component **170** may be performed by transceiver **302**.

Also, memory **316** may be configured to store data used herein and/or local versions of applications **375** or the communication component **160** and/or one or more subcomponents of the communication component **160** being executed by at least one processor **312**. Memory **316** may include any type of computer-readable medium usable by a computer or at least one processor **312**, such as random access memory (RAM), read only memory (ROM), tapes, magnetic discs, optical discs, volatile memory, non-volatile memory, and any combination thereof. In an aspect, for example, memory **316** may be a non-transitory computer-readable storage medium that stores one or more computer-executable codes defining the communication component **170** and/or one or more of its subcomponents, and/or data associated therewith, when the base station **105** is operating at least one processor **312** to execute the communication component **170** and/or one or more of the subcomponents.

Transceiver **302** may include at least one receiver **306** and at least one transmitter **308**. The at least one receiver **306** may include hardware, firmware, and/or software code executable by a processor for receiving data, the code comprising instructions and being stored in a memory (e.g., computer-readable medium). Receiver **306** may be, for example, a radio frequency (RF) receiver. In an aspect, receiver **306** may receive signals transmitted by the UE **110**. Transmitter **308** may include hardware, firmware, and/or software code executable by a processor for transmitting data, the code comprising instructions and being stored in a memory (e.g., computer-readable medium). A suitable example of transmitter **308** may including, but is not limited to, an RF transmitter.

Moreover, in an aspect, the base station **105** may include RF front end **388**, which may operate in communication with one or more antennas **365** and transceiver **302** for receiving and transmitting radio transmissions, for example, wireless communications transmitted by other base stations **105** or wireless transmissions transmitted by UE **110**. RF front end **388** may be coupled with one or more antennas **365** and may include one or more low-noise amplifiers (LNAs) **390**, one or more switches **392**, one or more power amplifiers (PAs) **398**, and one or more filters **396** for transmitting and receiving RF signals.

In an aspect, LNA **390** may amplify a received signal at a desired output level. In an aspect, each LNA **390** may have a specified minimum and maximum gain values. In an aspect, RF front end **388** may use one or more switches **392** to select a particular LNA **390** and the specified gain value based on a desired gain value for a particular application.

Further, for example, one or more PA(s) **398** may be used by RF front end **388** to amplify a signal for an RF output at a desired output power level. In an aspect, each PA **398** may have specified minimum and maximum gain values. In an aspect, RF front end **388** may use one or more switches **392** to select a particular PA **398** and the specified gain value based on a desired gain value for a particular application.

Also, for example, one or more filters **396** may be used by RF front end **388** to filter a received signal to obtain an input RF signal. Similarly, in an aspect, for example, a respective filter **396** may be used to filter an output from a respective PA **398** to produce an output signal for transmission. In an aspect, each filter **396** may be coupled with a specific LNA **390** and/or PA **398**. In an aspect, RF front end **388** may use one or more switches **392** to select a transmit or receive path using a specified filter **396**, LNA **390**, and/or PA **398**, based on a configuration as specified by transceiver **302** and/or processor **312**.

As such, transceiver **302** may be configured to transmit and receive wireless signals through one or more antennas **365** via RF front end **388**. In an aspect, transceiver may be tuned to operate at specified frequencies such that base station **105** may communicate with, for example, the UE **110** or one or more cells associated with one or more base stations **105**. In an aspect, for example, the modem **160** may configure transceiver **302** to operate at a specified frequency and power level based on the base station configuration of the base station **105** and the communication protocol used by the modem **160**.

In an aspect, the modem **160** may be a multiband-multimode modem, which may process digital data and communicate with transceiver **302** such that the digital data is sent and received using transceiver **302**. In an aspect, the modem **160** may be multiband and be configured to support multiple frequency bands for a specific communications protocol. In an aspect, the modem **160** may be multimode and be configured to support multiple operating networks and communications protocols. In an aspect, the modem **160** may control one or more components of the base station **105** (e.g., RF front end **388**, transceiver **302**) to enable transmission and/or reception of signals from the network based on a specified modem configuration. In an aspect, the modem configuration may be based on the mode of the modem and the frequency band in use. In another aspect, the modem configuration may be based on base station configuration associated with the base station **105**.

Turning now to FIG. **4**, the UE **110** may perform an example of a method **400** of wireless communications including beam failure detection using reference signals indicated in the control resource set.

At block **402**, the method **400** may perform the step of receiving a beam failure detection reference signal configu-

ration. For example, the communication component **150** of the UE **110** may receive a beam failure detection reference signal configuration transmitted by the communication components **170** of the base station **105**. The one or more antennas **265** of the UE **110** may receive electro-magnetic signals associated with the beam failure detection reference signal configuration. The RF front end **288** of the UE **110** may filter, amplify, and/or extract electrical signals carried by the electro-magnetic signals. The transceiver **202** or the receiver **206** of the UE **110** may digitize and convert the electrical signals into data, such as the beam failure detection reference signal configuration, and send to the communication component **222** of the UE **110**.

At block **404**, the method **400** may perform the step of detecting an absence of a configured and quasi-co-located BFD RS in at least one monitored control resource set. For example, the BFD component **152** of the UE **110** may detect an absence of a configured and quasi-co-located BFD RS in at least one monitored control resource set.

In some implementations, the at least one monitored control resource set may be configured by one or more MAC CEs.

In some implementations, detecting the absence may include detecting an incomplete configuration of the configured and quasi-co-located BFD RS. The incomplete configuration may indicate that the configuration of the quasi-co-located BFD RS has not been initiated or has not been completed.

In some implementations, the incomplete configuration may be caused by a RRC configuration latency. The UE **110** may receive at least one MAC CE and configure the at least one monitored CORESET or the configured and quasi-co-located BFD RS to reduce the RRC configuration latency.

In some implementations, configuring the at least one monitored CORESET or the configured and quasi-co-located BFD RS may include configuring the at least one monitored CORESET or the configured and quasi-co-located BFD RS in a same frame or different frames close in time. A non-limiting example of different frames close in time may include frames that differ by 1 microsecond (μs), 5 μs, 10 μs, 50 μs, 100 μs, 500 μs, or 1 millisecond (ms) in time.

In some implementations, detecting the absence may include determining a number of the at least one monitored CORESET is larger than a number of the BFD RS. For example, the UE **1109** may detect the absence by determining that there are three monitored CORESET and two configured BFD RSs.

At block **406**, the method **400** may perform the step of utilizing one or more reference signals indicated in a CORESET transmission configuration indicator state for beam failure detection. For example, the communication component **150** and/or the BFD component **152** of the UE **110** may utilize reference signals indicated in the CORESET transmission configuration indicator state for beam failure detection. In some examples, the UE **110** may utilize the one or more RSs in the CORESET transmission configuration indicator state for beam failure detection by evaluating the quality of the RSs (e.g., signal strength, signal to noise-plus-interference ratio, signal to noise ratio, bit error rate, block error rate, etc.). If the quality of the RSs degrade below a predetermined threshold, the UE **110** may determine a beam failure has occurred. For example, if the one or more RSs in the CORESET has a signal to noise-plus-interference ratio of 0.5 dB, and the predetermined threshold is 1 dB, the UE **110** may determine a beam failure event has occurred.

Turning now to FIG. **5**, the UE **110** may perform an example of a method **500** of wireless communications including beam failure detection using the demodulation reference signals of the control resource set.

At block **502**, the method **500** may perform the step of receiving a BFD RS configuration. For example, the communication component **150** of the UE **110** may receive a BFD RS configuration transmitted by the communication components **170** of the base station **105**. The one or more antennas **265** of the UE **110** may receive electro-magnetic signals associated with the beam failure detection reference signal configuration. The RF front end **288** of the UE **110** may filter, amplify, and/or extract electrical signals carried by the electro-magnetic signals. The transceiver **202** or the receiver **206** of the UE **110** may digitize and convert the electrical signals into data, such as the beam failure detection reference signal configuration, and send to the communication component **222** of the UE **110**.

At block **504**, the method **500** may perform the step of detecting an absence of a configured and quasi-co-located BFD RS in at least one monitored CORESET. For example, the BFD component **152** of the UE **110** may detect an absence of a configured and quasi-co-located BFD RS in at least one monitored CORESET.

In some implementations, the at least one monitored control resource set may be configured by one or more MAC CEs.

In some implementations, detecting the absence may include detecting an incomplete configuration of the configured and quasi-co-located BFD RS. The incomplete configuration may indicate that the configuration of the quasi-co-located BFD RS has not been initiated or has not been completed.

In some implementations, the incomplete configuration may be caused by a RRC configuration latency. The UE **110** may receive at least one MAC CE and configure the at least one monitored CORESET or the configured and quasi-co-located BFD RS to reduce the RRC configuration latency.

In some implementations, configuring the at least one monitored CORESET or the configured and quasi-co-located BFD RS may include configuring the at least one monitored CORESET or the configured and quasi-co-located BFD RS in a same frame or different frames close in time. A non-limiting example of different frames close in time may include frames that differ by 1 microsecond (μs), 5 μs, 10 μs, 50 μs, 100 μs, 500 μs, or 1 millisecond (ms) in time.

In some implementations, detecting the absence may include determining a number of the at least one monitored CORESET is larger than a number of the BFD RS. For example, the UE **1109** may detect the absence by determining that there are three monitored CORESET and two configured BFD RSs.

At block **506**, the method **500** may perform the step of utilizing demodulation reference signals of the at least one monitored CORESET or decoding statistics of a PDCCH by the at least one monitored CORESET to evaluate a CORESET quality for beam failure detection. For example, the BFD component **152** of the UE **110** may utilize demodulation reference signals of the at least one monitored CORESET or decoding statistics of a PDCCH carried by the at least one monitored CORESET to evaluate a CORESET quality for beam failure detection.

Turning now to FIG. **6**, the UE **110** may perform an example of a method **600** of wireless communications including beam failure detection using configured and quasi-co-located beam failure detection reference signals.

At block **602**, the method **600** may perform the step of receiving a BFD RS configuration. For example, the communication component **150** of the UE **110** may receive a BFD RS configuration transmitted by the communication components **170** of the base station **105**. The one or more antennas **265** of the UE **110** may receive electro-magnetic signals associated with the beam failure detection reference signal configuration. The RF front end **288** of the UE **110** may filter, amplify, and/or extract electrical signals carried by the electro-magnetic signals. The transceiver **202** or the receiver **206** of the UE **110** may digitize and convert the electrical signals into data, such as the beam failure detection reference signal configuration, and send to the communication component **222** of the UE **110**.

At block **604**, the method **600** may perform the step of waiting until a configuration of corresponding quasi-co-located BFD RS is complete. For example, the BFD component **152** of the UE **110** may wait until configuration of corresponding quasi-co-located BFD RS is complete.

In some implementations, the UE **110** may perform the step of configuring, prior to utilizing the corresponding quasi-co-located BFD RS, at least one monitored CORESET or the corresponding quasi-co-located BFD RS using one or more medium access control (MAC) control elements (CEs). In some implementations, configuring the at least one monitored CORESET or the corresponding quasi-co-located BFD RS may include configuring the at least one monitored CORESET or the corresponding quasi-co-located BFD RS in a same frame or different frames close in time. A non-limiting example of different frames close in time may include frames that differ by 1 microsecond (μs), 5 μs, 10 μs, 50 μs, 100 μs, 500 μs, or 1 millisecond (ms) in time.

At block **606**, the method **600** may perform the step of utilizing the configured and quasi-co-located BFD RS for beam failure detection. For example, the BFD component **152** of the UE **110** may utilize the configured and quasi-co-located BFD RS for beam failure detection.

In optional implementations, the UE **110** may configure, prior to utilizing the configured and quasi-co-located BFD RS, a CORESET and a corresponding quasi-co-located BFD RSs by one or more MAC CEs. For example, the BFD component **152** of the UE **110** may configure a CORESET and corresponding quasi-co-located BFD RSs by one or more MAC CEs to reduce the latency associated with RRC configuration and/or reconfiguration operations.

The above detailed description set forth above in connection with the appended drawings describes examples and does not represent the only examples that may be implemented or that are within the scope of the claims. The term "example," when used in the description, means "serving as an example, instance, or illustration," and not "preferred" or "advantageous over other examples." The detailed description includes specific details for the purpose of providing an understanding of the described techniques. These techniques, however, may be practiced without these specific details. For example, changes may be made in the function and arrangement of elements discussed without departing from the scope of the disclosure. Also, various examples may omit, substitute, or add various procedures or components as appropriate. For instance, the methods described may be performed in an order different from that described, and various steps may be added, omitted, or combined. Also, features described with respect to some examples may be combined in other examples. In some instances, well-known structures and apparatuses are shown in block diagram form in order to avoid obscuring the concepts of the described examples.

It should be noted that the techniques described herein may be used for various wireless communication networks such as CDMA, TDMA, FDMA, OFDMA, SC-FDMA, and other systems. The terms "system" and "network" are often used interchangeably. A CDMA system may implement a radio technology such as CDMA2000, Universal Terrestrial Radio Access (UTRA), etc. CDMA2000 covers IS-2000, IS-95, and IS-856 standards. IS-2000 Releases 0 and A are commonly referred to as CDMA2000 1×, 1×, etc. IS-856 (TIA-856) is commonly referred to as CDMA2000 1×EV-DO, High Rate Packet Data (HRPD), etc. UTRA includes Wideband CDMA (WCDMA) and other variants of CDMA. A TDMA system may implement a radio technology such as Global System for Mobile Communications (GSM). An OFDMA system may implement a radio technology such as Ultra Mobile Broadband (UMB), Evolved UTRA (E-UTRA), IEEE 802.11 (Wi-Fi), IEEE 802.16 (WiMAX), IEEE 802.20, Flash-OFDM™, etc. UTRA and E-UTRA are part of Universal Mobile Telecommunication System (UMTS). 3GPP LTE and LTE-Advanced (LTE-A) are new releases of UMTS that use E-UTRA. UTRA, E-UTRA, UMTS, LTE, LTE-A, and GSM are described in documents from an organization named "3rd Generation Partnership Project" (3GPP). CDMA2000 and UMB are described in documents from an organization named "3rd Generation Partnership Project 2" (3GPP2). The techniques described herein may be used for the systems and radio technologies mentioned above as well as other systems and radio technologies, including cellular (e.g., LTE) communications over a shared radio frequency spectrum band. The description herein, however, describes an LTE/LTE-A system or 5G system for purposes of example, and LTE terminology is used in much of the description below, although the techniques may be applicable other next generation communication systems.

Information and signals may be represented using any of a variety of different technologies and techniques. For example, data, instructions, commands, information, signals, bits, symbols, and chips that may be referenced throughout the above description may be represented by voltages, currents, electromagnetic waves, magnetic fields or particles, optical fields or particles, computer-executable code or instructions stored on a computer-readable medium, or any combination thereof.

The various illustrative blocks and components described in connection with the disclosure herein may be implemented or performed with a specially-programmed device, such as but not limited to a processor, a digital signal processor (DSP), an ASIC, a FPGA or other programmable logic device, a discrete gate or transistor logic, a discrete hardware component, or any combination thereof designed to perform the functions described herein. A specially-programmed processor may be a microprocessor, but in the alternative, the processor may be any conventional processor, controller, microcontroller, or state machine. A specially-programmed processor may also be implemented as a combination of computing devices, e.g., a combination of a DSP and a microprocessor, multiple microprocessors, one or more microprocessors in conjunction with a DSP core, or any other such configuration.

The functions described herein may be implemented in hardware, software executed by a processor, firmware, or any combination thereof. If implemented in software executed by a processor, the functions may be stored on or transmitted over as one or more instructions or code on a non-transitory computer-readable medium. Other examples and implementations are within the scope and spirit of the

disclosure and appended claims. For example, due to the nature of software, functions described above may be implemented using software executed by a specially programmed processor, hardware, firmware, hardwiring, or combinations of any of these. Features implementing functions may also be physically located at various positions, including being distributed such that portions of functions are implemented at different physical locations. Also, as used herein, including in the claims, "or" as used in a list of items prefaced by "at least one of" indicates a disjunctive list such that, for example, a list of "at least one of A, B, or C" means A or B or C or AB or AC or BC or ABC (i.e., A and B and C).

Computer-readable media includes both computer storage media and communication media including any medium that facilitates transfer of a computer program from one place to another. A storage medium may be any available medium that may be accessed by a general purpose or special purpose computer. By way of example, and not limitation, computer-readable media may comprise RAM, ROM, EEPROM, CD-ROM or other optical disk storage, magnetic disk storage or other magnetic storage devices, or any other medium that may be used to carry or store desired program code means in the form of instructions or data structures and that may be accessed by a general-purpose or special-purpose computer, or a general-purpose or special-purpose processor. Also, any connection is properly termed a computer-readable medium. For example, if the software is transmitted from a website, server, or other remote source using a coaxial cable, fiber optic cable, twisted pair, digital subscriber line (DSL), or wireless technologies such as infrared, radio, and microwave, then the coaxial cable, fiber optic cable, twisted pair, DSL, or wireless technologies such as infrared, radio, and microwave are included in the definition of medium. Disk and disc, as used herein, include compact disc (CD), laser disc, optical disc, digital versatile disc (DVD), floppy disk and Blu-ray disc where disks usually reproduce data magnetically, while discs reproduce data optically with lasers. Combinations of the above are also included within the scope of computer-readable media.

The previous description of the disclosure is provided to enable a person skilled in the art to make or use the disclosure. Various modifications to the disclosure will be readily apparent to those skilled in the art, and the common principles defined herein may be applied to other variations without departing from the spirit or scope of the disclosure. Furthermore, although elements of the described aspects may be described or claimed in the singular, the plural is contemplated unless limitation to the singular is explicitly stated. Additionally, all or a portion of any aspect may be utilized with all or a portion of any other aspect, unless stated otherwise. Thus, the disclosure is not to be limited to the examples and designs described herein but is to be accorded the widest scope consistent with the principles and novel features disclosed herein.

What is claimed is:

1. A method of wireless communication, comprising:

receiving a beam failure detection (BFD) reference signal (RS) configuration;

detecting an absence of a configured and quasi-co-located BFD RS associated with the BFD RS configuration in at least one monitored control resource set (CORESET), wherein detecting the absence comprises detecting an incomplete configuration of the configured and quasi-co-located BFD RS; and

utilizing one or more RSs indicated in a CORESET transmission configuration indicator (ICI) state for beam failure detection.

2. The method of claim **1**, wherein the at least one monitored CORESET is configured by one or more medium access control (MAC) control elements (CEs).

3. The method of claim **1**, wherein the incomplete configuration is caused by a radio resource control (RRC) configuration latency.

4. The method of claim **3**, further comprises:

receiving at least one MAC CE; and

configuring the at least one monitored CORESET or the configured and quasi-co-located BFD RS to reduce the RRC configuration latency.

5. The method of claim **4**, wherein configuring the at least one monitored CORESET or the configured and quasi-co-located BFD RS comprises configuring the at least one monitored CORESET or the configured and quasi-co-located BFD RS in a same frame or different frames.

6. The method of claim **1**, wherein detecting the absence comprises determining a number of the at least one monitored CORESET is larger than a number of the BFD RS.

7. A method of wireless communication, comprising:

receiving a beam failure detection (BFD) reference signal (RS) configuration;

detecting an absence of a configured and quasi-co-located BFD RS associated with the BFD RS configuration in at least one monitored control resource set (CORESET), wherein detecting the absence comprises detecting an incomplete configuration of the configured and quasi-co-located BFD RS; and

utilizing one or more demodulation RSs of the at least one monitored CORESET or decoding statistics of a physical downlink control channel (PDCCH) carried by the at least one monitored CORESET to evaluate a CORESET quality for beam failure detection.

8. The method of claim **7**, wherein the at least one monitored CORESET is configured by one or more medium access control (MAC) control element (CE).

9. The method of claim **7**, wherein the incomplete configuration is caused by a radio resource control (RRC) configuration latency.

10. The method of claim **9**, further comprises:

receiving at least one MAC CE; and

configuring the at least one monitored CORESET or the configured and quasi-co-located BFD RS to reduce the RRC configuration latency.

11. The method of claim **10**, wherein configuring the at least one monitored CORESET or the configured and quasi-co-located BFD RS comprises configuring the at least one monitored CORESET or the configured and quasi-co-located BFD RS in a same frame or different frames.

12. The method of claim **7**, wherein detecting the absence comprises determining a number of the at least one monitored CORESET is larger than a number of the BFD RS.

13. A method of wireless communication, comprising:

receiving a beam failure detection (BFD) reference signal (RS) configuration;

waiting until a configuration of a corresponding quasi-co-located BFD RS in a monitored control resource set (CORESET) is complete; and

utilizing the corresponding quasi-co-located BFD RS for beam failure detection in response to a completion of the configuration of the corresponding quasi-co-located BFD RS in the monitored CORESET.

14. The method of claim **13**, further comprising:

configuring, prior to utilizing the corresponding quasi-co-located BFD RS, at least one monitored CORESET or

the corresponding quasi-co-located BFD RS using one or more medium access control (MAC) control elements (CEs).

15. The method of claim **14**, wherein configuring the at least one monitored CORESET or the corresponding quasi-co-located BFD RS comprises configuring the at least one monitored CORESET or the corresponding quasi-co-located BFD RS in a same frame or different frames.

16. A user equipment, comprising:

a memory;

a transceiver;

one or more processors operatively coupled with the memory and the transceiver, the one or more processors configured to perform the steps of:

receiving, via the transceiver, a beam failure detection (BFD) reference signal (RS) configuration;

detecting an absence of a configured and quasi-co-located BFD RS associated with the BFD RS configuration in at least one monitored control resource set (CORESET), wherein detecting the absence comprises detecting an incomplete configuration of the configured and quasi-co-located BFD RS; and

utilizing one or more RSs indicated in a CORESET transmission configuration indicator (TCI) state for beam failure detection.

17. The user equipment of claim **16**, wherein the at least one monitored CORESET is configured by one or more medium access control (MAC) control elements (CEs).

18. The user equipment of claim **16**, wherein the incomplete configuration is caused by a radio resource control (RRC) configuration latency.

19. The user equipment of claim **18**, wherein the one or more processor is configured to perform the steps of:

receiving at least one MAC CE; and

configuring the at least one monitored CORESET or the configured and quasi-co-located BFD RS to reduce the RRC configuration latency.

20. The user equipment of claim **19**, wherein configuring the at least one monitored CORESET or the configured and quasi-co-located BFD RS comprises configuring the at least one monitored CORESET or the configured and quasi-co-located BFD RS in a same frame or different frames.

21. The user equipment of claim **16**, wherein detecting the absence comprises determining a number of the at least one monitored CORESET is larger than a number of the BFD RS.

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